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Recipes for Change: Papas a la Huancaina in Bolivia

Summary statement

The main climate risks to potato agriculture in the main cultivation regions of Bolivia are: (i) increased temperatures, and potential effects on growth and transpiration rates; (ii) enhanced climatic variability and prevalence of extreme events, primarily in the intensity and frequency of precipitation levels and temperature; (iii) consequent effects on the growing season.

The key adaptation measures for managing the foreseen impacts of climate change within the region are: (i) improved water management and cultivation practices; (ii) improved cultivars, including the adoption of temperature and drought resilient varieties; and (iii) promoting access to, and ensuring continued support of, assets (human, social, financial, political) necessary for coping with both climatic and non-climatic stressors.

CCAFS validates the climate threats and solutions highlighted in the IFAD statements below. CCAFS also identifies the fact that the livelihoods of farmers engaged in potato production in Bolivia are subject to multiple stressors, many of which are linked with (but not primarily driven by) changes in the climate. Alleviation of the risks posed by climate change therefore also entails alleviating risks posed by non-climatic stressors.

CCAFS also notes that IFAD lists the introduction of 'hardy varieties' as one of their ASAP solutions. However, it is not clear if this means 'improved' varieties developed through a formal breeding programme, or the transfer of local landraces and varieties between locations in order to exploit existing traits. Both may be valid adaptation responses. CCAFS would also add the importance of ex situ and in situ conservation of genetic diversity, for example in Peru at the CIP genebank and at the Parque de la Papa, as critical resources for current and future adaptation.

IFAD-identified climate threats to potatoes:

- *Increased temperatures*
- *Changes in growing seasons*
- *Increased incidence of extreme weather events*

ASAP solutions:

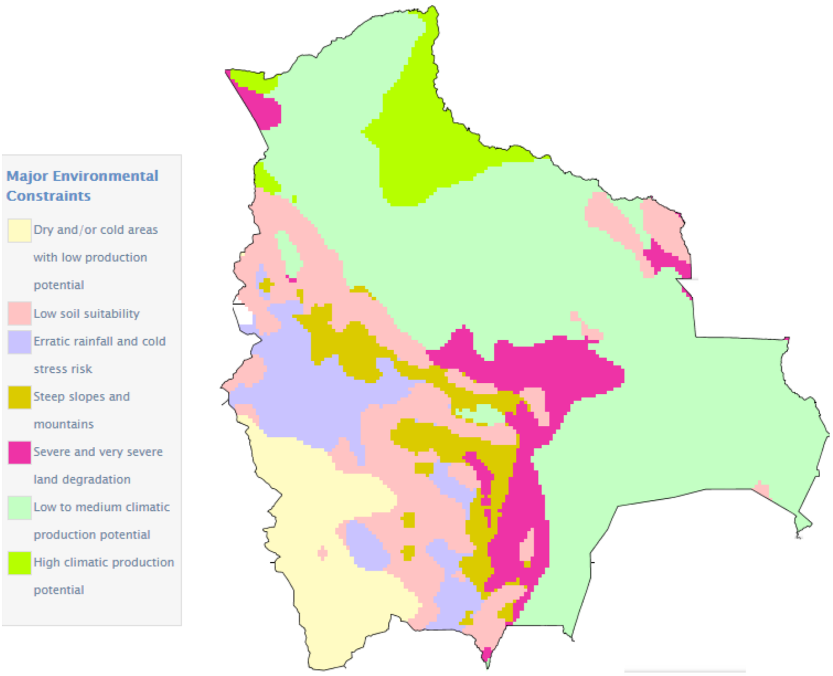
- *Introduction of more appropriate and hardy varieties of potatoes*
- *More sustainable practices with yields maintained or even increased*

Climate risks and responses in Bolivia

The potato is indigenous to the Andean region and has been cultivated in the area for over 8000 years. Across the Americas some 200 species and several thousands of varieties of potatoes can be found, a result of the concerted efforts of farmers in cultivar selection and improvement (FAO, 2008). But today just a small subset are cultivated commercially at scale and it is the single Solanum species, tuberosum, which reigns supreme as the world’s fourth most important food staple by weight (FAO, 2008). Specific to the Andean region, seven species of potato are currently grown, the subspecies Solanum tuberosum ssp. Andigenum being the most widely cultivated and also the most prevalent in the Bolivian market (Quiros et al., 1990; Condori et al., 2008). Although per-capita consumption has fallen in recent decades, potato still remains the most important staple in Boliva. The majority of potato cultivation in Bolivia is centred within the high plains of the Altiplano and inter-Andean valleys, with the majority of Bolivia's farmers living within these regions. Maintaining a livelihood from this high, dry and cold land is difficult particularly as the region has the least fertile soils and the least rain (NewAg, 2014). Bolivia has the highest percentage of people living in poverty in South America, with approximately 60 per cent below the national poverty line, a share which rises up to 75% in rural areas (IFAD, 2013). At the same time, resources for investment in agricultural inputs are limited and farming methods generally remain traditional, with terraced fields and foot or oxen ploughs. These methods leave crops vulnerable to frost, variable rainfall and erosion (CIP, 2014). Furthermore, the results in terms of yields are lacking: some 30% less than the yield levels reached in neighbouring Ecuador, and less than half of the average potato yield in Peru (FAO, 2014).

Numerous factors contribute to the overall vulnerability of potato production in Bolivia. They include: (i) poor management of natural resources, (ii) changes in land use and deforestation, (iii) limited means for intensification and modernisation and (iv) a lack of security in land tenure and unequal land distribution. In addition to these factors, cultivation also risks negative impacts consequent of the exposure to several climatic hazards, most of which pose an increasing threat under ongoing climate change. This brief report details each of the major climate hazards in turn before concluding with options for the management of risks and adaptation to expected impacts.

Figure 1: Major environmental constraints to agriculture in Bolivia[1]



Increased temperatures and consequent changes in growing season and extreme events

Increased temperatures lead to a number of complex and interlinked impacts to potato cultivation. Firstly, elevated concentrations of atmospheric carbon dioxide (CO_2) will likely lead to a fertilization effect, as the greater availability of CO_2 stimulates the development of underground biomass in tubers (Högy & Fangmeier, 2009). However, the net

[1] Source FAO: http://www.fao.org/countryprofiles/maps/map/en/?iso3=BOL&mapID=604

impact of this fertilization effect is poorly quantified, when balanced against other impacts, such as increased water stress through enhanced transpiration rates (ibid).

Potatoes are indigenous to the high-altitude tropics but flourish today also in temperate climates. Generally, growth of the tuber is inhibited at temperatures outside of an optimum temperate range, and severe damage may occur when temperatures drop below the freezing point (Hijmans, 2003). In the high Andes, the impact of increased temperatures is to shift this optimal temperate 'cultivation window' to high altitudes. However, high altitudes outside of the plateau region may not be suited to cultivation, as the relief of the land is unworkable and competition may exist between cultivation and pasture. Additionally, higher temperatures increase respiration and development rates of the plant, potentially leading to lower yields (Hijmans, 2003). Yet, faster development can be beneficial in escaping drought or frost at the edges of the growing season. And warming may lead to an overall lengthening of the growth season if temperatures remain within favorable limits (Hijmans, 2003).

The rate of temperature increase in the Andean region is projected at two or more times those projected for average temperature increases at the wider scale (Bradley et al., 2006). Therefore, in addition to increased maximum temperatures, diurnal temperature variation will likely be enhanced, as well as variation in relative humidity, cloud and fog cover, and insolation (Buytaert et al., 2006; Ruiz et al., 2008). An intensification of the hydrological cycle is also likely with a warmer climate. Changes in precipitation levels and seasonality are expected, with a number of studies predicting more dramatic seasonal variation in precipitation in the Altiplano, with a possible decrease in September-November rains and an increase in the precipitation for the December-February period (Perez et al., 2010). Projections for the longer term are subject to uncertainty, but under high-warming scenarios, suggest an overall reduction in annual levels of precipitation in the Andean region of around 15% by late century (Magrin et al., 2013). The outcome of this is a likely reduction of soil moisture and groundwater reserves, and greater frequency of drought or flooding (Beniston, 2005). Changes in the hydrological cycle will also be affected by glacial retreat and the ensuing changes in runoff. In the near-term, runoff tends to increase due to accelerated melting. But in the medium and longer term, glacier-fed water reservoirs will empty, causing runoff and overall water availability to decrease. As glacier melt is the major contribution to runoff in the dry season, existing water stress and drought prevalence is likely to increase in this period of the season. Glacial retreat also introduces potential threats of landslides and mudflows as ice slopes are destabilized (Perez et al., 2010).

Variability is a key feature of South American climates. Year-to-year variations in precipitation can be substantial and are caused primarily by the El Niño-Southern Oscillation (ENSO) phenomenon. During El Niño conditions, significant moisture transport from the Amazon basin is inhibited causing drought conditions over the tropical Andes, in particular over the Altiplano region of Bolivia (Garreaud et al., 2003). The opposite effect is generally seen during the counter cycle, La Niña (ibid). However, this general pattern of variation is itself not always consistent and further predictions of how such inter-annual variation may evolve under ongoing climate change remains uncertain (Collins et al., 2010). Superimposed upon this variability is shorter term, intra-annual variation. Again climate and hydrological model uncertainties, along with the complex Andean topography obscure predictions for the region. However, best estimates are in line with already observed increases in temperature and precipitation variability, adding confidence to a continuation of this trend in increasing climatic variability (Thibeault, 2010).

A changing climate may also impact upon the prevalence of agricultural pests and diseases. Rising temperatures will allow an expansion in the range of insect species to higher altitudes, increases in diversity of insect herbivores and their intensified activity. The effectiveness of some pesticides also decreases with high temperatures and precipitation. Warmer and wetter conditions during the growing season are favourable to fungal and bacterial pathogens, while water stress from decreased precipitation during the dry season reduces plants' resilience to pathogen attacks. Late blight is one of the main diseases affecting cultivation in the highland tropics. The existence of other late blight hosts, such as tomato, and the fact that potatoes are cultivated over a long period of the year add to the susceptibility to this disease. Areas with the greatest relative change in temperature and moisture (such as the high Andes) are expected to be among those with the greatest increase in late blight risk (Sparks et al., 2014).

Adaptation to climate hazards

Options for managing the main climate hazards to potato cultivation on the Bolivian high-plateau centre include the use of improved cropping practices and resource management, as well as the development and use of more resilient cultivars.

Agriculture in the Andean region has developed under conditions of climatic variability, resulting in numerous strategies designed to optimise production and cope with uncertain conditions. Primarily, this includes matching of varieties to biophysical conditions, multicropping, terracing and intercropping of multiple varieties in the same plot (Thiele, 1999). Cultivating many plots in different zones can maximize altitude, sun exposure and soil fertility differentials, a further hedge against variability. This has been combined with staggered planting dates and across varieties, in an attempt to match rainfall and temperature patterns. Traditional practices of freeze-drying potato can be used to produce Chuño, a non-perishable dehydrated product suitable for storing the produce of good harvest across seasons (Arbizu & Tapia 1994). A recent study commissioned by the United Nations Development Programme (UNDP) recorded an ongoing adjustment of production practices in recent decades, including upward migration of crops, selection of more resistant varieties and water capturing. Climatic changes were seen as one of the driving forces, along with other interlinked stressors such as soil degradation and population pressure (PNCC, 2007).

Improved resource management and a shift in farming practices provide options for mitigating the risks posed by water scarcity. With limited overall water supply in the Altiplano, deficit irrigation could be an effective measure for efficient increases in productivity. This practice was shown to be twice as efficient in its water than conventional full irrigation in the production of quinoa in the arid Altiplano (Geerts & Raes, 2008).

Improved varieties, either through plant breeding techniques or genetic modification, can improve plant tolerance under environmental stressors. Depending on the variety, heat tolerance can improve performance under either high or low temperature conditions. Tolerance to frost, a trait exhibited by bitter potato varieties, means that crops are not only less vulnerable to damage, but their cultivation can also expand upward to cooler regions where the terrain is favourable. Resilience to higher temperatures is closely tied with drought-tolerance, as transpiration rates in potato plants increase with temperature. Crop diversification and the implementation of improved varieties may also alleviate existing plant disease pressures. This practice has been evidenced in neighbouring Peru, where outbreaks were shown to be lessened and pathogen transmission dampened as a result of crop diversification (Lin, 2011). In a trial run by the International Potato Center (CIP) in the Peruvian Andes, it was shown how the adoption of the late blight resistant Amarilis variety could simultaneously increase yields and lower the use of fungicides (Salazar, 2009).

Additional approaches to adaptation involve alleviating the non-climatic stressors (social, economic, political, and environmental) which influence production. Studies with indigenous farmers in highland Bolivia and Peru indicate that constraints on access to key resources are the barriers preventing farmers from confronting multiple stressors (McDowell & Hess, 2012; Sietz et al., 2012). Lessening the risk of negative impacts resulting from multiple stressors cannot be achieved by focussing interventions on a single stressor, such as the climate. Instead, the focus should be on sustaining access to assets so that households and communities can confront multiple stressors according to their own priorities, and thus improve current livelihoods and reduce vulnerability in the long term. One example of this is the support of community-appointed irrigation committees, which have been established in areas where formal state support to improve water access has not been forthcoming (McDowell & Hess, 2012). Such forums hold vital social capital, whether in local knowledge, the mediation of local decision-making or in mobilising labour for common goals, such as for minor infrastructure improvements (ibid.). Furthermore, innovative measures can help support farmers with the resources they most need, such as access to information and finance. For example, access to and improvement of climate forecast information has been shown to enhance the planning abilities of farmers in the Brazilian Amazon in coping with the impacts of El Niño (Moran et al., 2006). In Peru, an insurance scheme has been developed that makes use of index-based forecast insurance which pays out on the basis of a seasonal forecast. This gives the farmer the power to use the payout for preventive measures, in anticipation of possible income reduction (GIZ, 2012).

Mitigation

The low intensity of agricultural systems in Bolivia implies that mitigation potentials on the input side are also limited. Managing emissions in this type of agricultural setting is a matter of managing resources sustainably (particularly land and soils). As uncultivated, pasture or fallow land is bought into cultivation the associated biological and physical processes result in a release of soil organic carbon. Up to 50% of stored soil carbon can be released depending on soil conditions and agricultural practices (Antle, 2007).

Depending on the setting, several management practices can be employed to increase soil carbon as well as aboveground carbon in biomass. These include soil conservation practices (e.g. reduced tillage, terracing), incorporation of crop residues into soils, increases in cropping intensity and fertilization, and conversion or restoration of cropland and degraded land to permanent grasses or trees (Lal et al., 1998). Soil erosion is a major cause of loss of productivity across much of the Andean region. This is a result of many years of deforestation and clearing as more marginal land is increasingly used for crop production. Slowing the rate of soil erosion will increase soil moisture availability and enhance soil fertility. Live barriers and terracing combined with improved water management and fertilizer application have been identified as suitable options for achieving this (Coker & Flores, 1999). Not only do these practices contribute to enhanced productivity, they also allow forest reserves to be protected and land unsuited for crop or livestock to be used for reforestation, thus reducing the overall loss of soil and aboveground carbon (Ellis-Jones & Mason, 1999).

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